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A SEMI-AUTOMATIC SYSTEM FOR DIGITIZING BATHYMETRY CHARTS

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Calspan Corporation

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Technical Report

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R.B. Solosko

Calspan Report No. VF-5206-X-1

31

Calspan

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Details of illustrations in this document may be better studied on microfiche

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THE LONG RANGE ACOUSTIC PROPAGATION PROJECT
OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
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ABSTRACT

In support of the Long Range Acoustic Propagation Project (LRAPP), Office of Naval Research, Calspan Corporation has implemented a semi-automatic system for digitizing bathymetry charts. This system encodes the contour depth information in the following way. The bathymetry chart is overlayed by a set of parallel lines called track lines. The intersections of these track lines with the contour lines on the chart define the locations of points where the depth information is to be encoded.

The initial step in the process for semi-automatically digitizing bathymetry charts is to scan the chart to produce a digital image which is displayed for the operator on a digital image display. By moving a cursor on the digital image display, the operator then indicates the locations of implicit fiducial marks on the chart image to establish a longitude and latitude reference for the chart coordinate system. The location of the set of parallel track lines is then drawn over the image of the chart for the operator's convenience. The bathymetry chart is re-scanned over the first track line and the intersections of the contourswith the track line are then automatically detected and displayed to the operator. Next, depth information of the contour detections along the track lines are automatically assigned if enough data is available. The operator may then interact with the system to add missing contour detections, delete extraneous contour detections, and provide the necessary additional contour depth data. The track lines contour depth data is then written on a magnetic tape and the next track line of the set is scanned. This process is repeated until all track lines have been scanned and the contour depth data has been encoded.

This bathymetry digitizing system, implemented on Calspan owned equipment, will be used to digitize the 600 bathymetry charts which describe the undersea topography of the world.

ACKNOWLEDGEMENTS

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Section 1

INTRODUCTION

The Long Range Acoustic Propagation Project (LRAPP) of the Office of Naval Research (ONR) needs for its acoustic propagation studies a data base of ocean bottom depth information. This data base will be generated by digitizing contour maps (called bathymetry charts) of the ocean floor. The purpose of the project described in this report is to develop a facility to digitize these maps, that is to encode in digital form the depth information from bathymetry charts. This facility is now complete.

Image processing techniques were implemented by Calspan Corporation in a computer interactive system to perform the digitizing operation. The project consisted of developing a computer software system to implement the required digitizing functions. The software runs on equipment owned by Calspan and operated as components of its Image Processing Laboratory. The chart digitizing facility which has been developed will now be used to encode the approximately 600 bathymetry charts which describe the undersea topography of the oceans of the world.

This report describes the digitizing operations performed by the system and the form of the input and output data. Results of the system performance evaluation are also given.

Section 2

DIGITIZING REQUIREMENTS

The LRAPP requires the generation of a data base of ocean depth information. The data is to have the form of a grid of data points where each point is described by its latitude, longitude, and depth. The first step in the generation of the data base is the establishment of a coarse grid of depth information; the second step is the use of an interpolation program to fill out the grid of depth information. That is, a fine grid is generated from the coarse grid by interpolation. The project described here is the development of a system to do the first step; the second or interpolation step is performed at ONR.

The initial grid of depth information is defined in the following way. The bathymetry chart is overlaid by a set of parallel lines, called track lines, and the intersections of these track lines with the contour lines on the chart define the points where the depth information is to be encoded. The system is used to digitize the depth information at these points and record it on magnetic tape. The orientation of the set of parallel track lines is chosen to give the most useful information. When there is a dominant slope direction, the set of track lines is oriented in the direction of the maximum rate of change of the depth. On most charts there is not a predominant direction and on these charts the track lines are oriented east and west. In areas of steep slope, for example at sea mounts, auxiliary track lines are added at the best orientation to better define these features.

The bathymetry charts digitized in this fashion for ONR are Mercator projections and each covers approximately a $5^{\circ} \times 5^{\circ}$ area. The scale of the charts ranges from 300,000:1 to 800,000:1, depending on the latitude. The track lines are spaced at 5 minute intervals. The depths are recorded in the units on the chart, either fathoms or meters, and the data is written on magnetic tape in a format compatible with ONR's computer facilities.

Section 3

DESCRIPTION OF THE BATHYMETRY CHART DIGITIZING FACILITY

Figure 1 shows Calspan's Image Processing Laboratory configured for digitizing bathymetry charts. The chart encoding facility utilizes a flying spot scanner, a PDP-9 computer, a digital image display, a keyboard terminal and a track ball.

The flying spot scanner scans a 2-1/2 inch square area in an array of 1024 by 1024 points. Each point in the image field in the flying spot scanner is defined by one of 64 values depending on the gray level of the image under the spot. The scanner is random addressable and thus selected areas of the image can be scanned or the image can be scanned in selected patterns. For use in Calspan's flying spot scanner, the bathymetry charts are divided into four sections and each section is photographed onto 70mm film. The film is thus scanned in the flying spot scanner. The PDP-9 computer, is used for general computation and control. The track ball is used to move a cursor on the digital image display, thereby allowing the operator to select specific points on the image for processing. The cursor may also be controlled by the PDP-9 computer independent of the track ball. The keyboard terminal, which includes an LED alphanumeric display, is used for providing the operator with instructions and information and for entering depth and coordinate information.

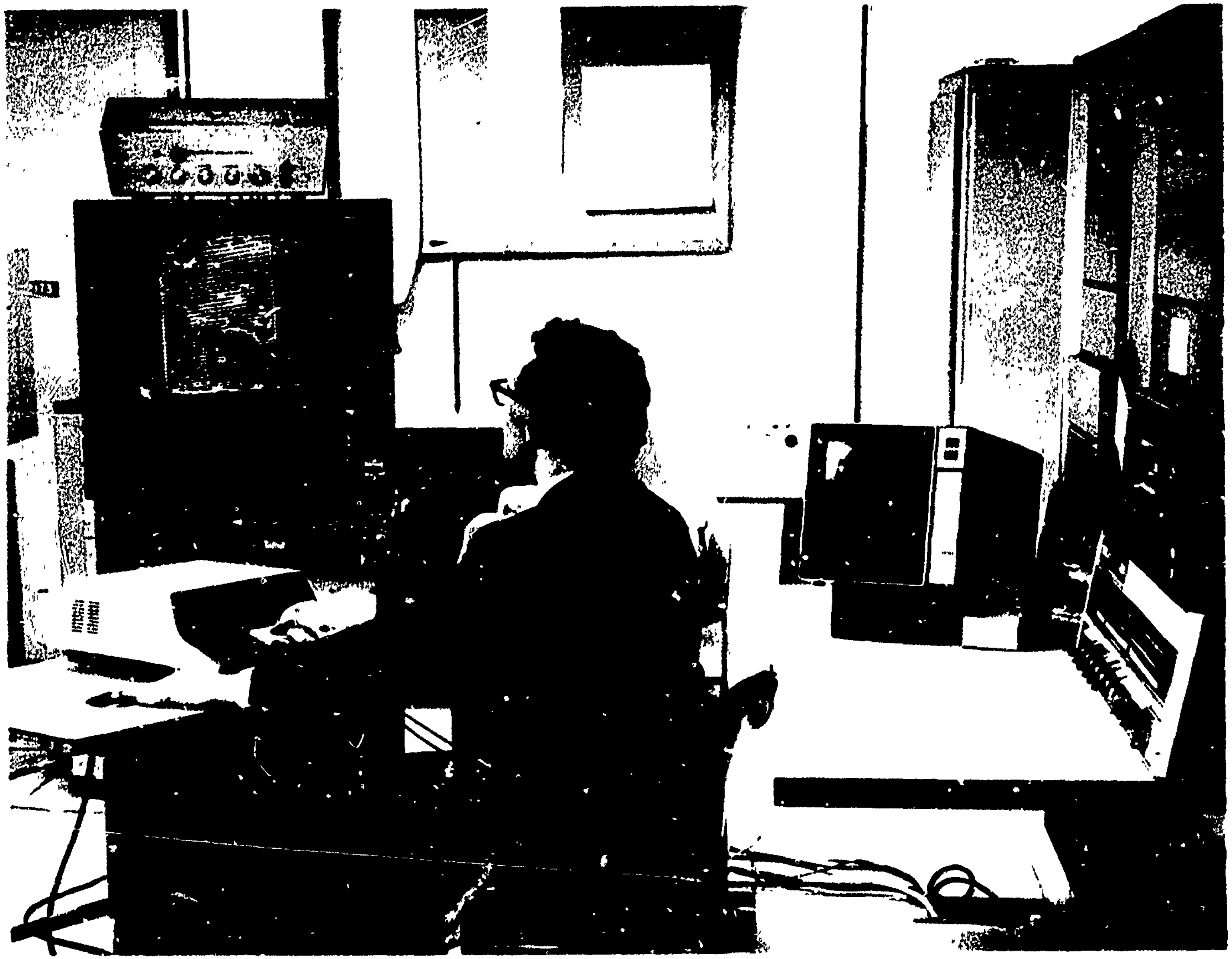

Figure 1 CALSPAN'S IMAGE PROCESSING LABORATORY FACILITY CONFIGURED FOR DIGITIZING BATHYMETRY CHARTS

Section 4

OPERATION OF THE FACILITY

Figure 2 shows a flow diagram of the process used for digitizing bathymetry charts. Each chart is photographed onto 70mm film with four frames corresponding to the four sections for a chart. Each of the four sections is processed separately. Initially the operator manually enters the longitude and latitude of the lower left hand corner of the chart, the chart identification number (the MSQLOC number), the date, and information relating to the desired direction of the parallel track lines. The negative on 70mm film corresponding to the first section of the chart (the lower left hand quadrant) is scanned in the flying spot scanner and displayed for the operator on the digital image display. Using the track ball to move a cursor on the screen the operator then manually locates the coordinate axes on the chart image.

At the completion of the entry of the location of the coordinate axes of the chart image, the system then draws a set of lines over the chart image which indicates the locations of the track lines. Figure 3 shows a typical display as seen by the operator on the digital image display. After the track lines are displayed for the operator, the system rescans the chart along the first track line, detects the intersections of the contours with the track line and indicates the locations of these contour detections to the operator by drawing an arrow on the track line display with the head of the arrow on the detected contour (see figure 3). The track line detection process has the ability to discriminate between well defined contours and characters and other noise on the chart image. Only well defined contours are indicated for the operator as a contour detection. Coordinate lines "look" like contours and thus they will normally be detected as contours. Since their location can be predicted, the system automatically eliminates these "contour" detections at these predicted locations before they are displayed to the operator.

The process for assigning depth information to the contour detections, for adding missing detections, and for eliminating false detections is performed in an interactive mode. The system provides several completely

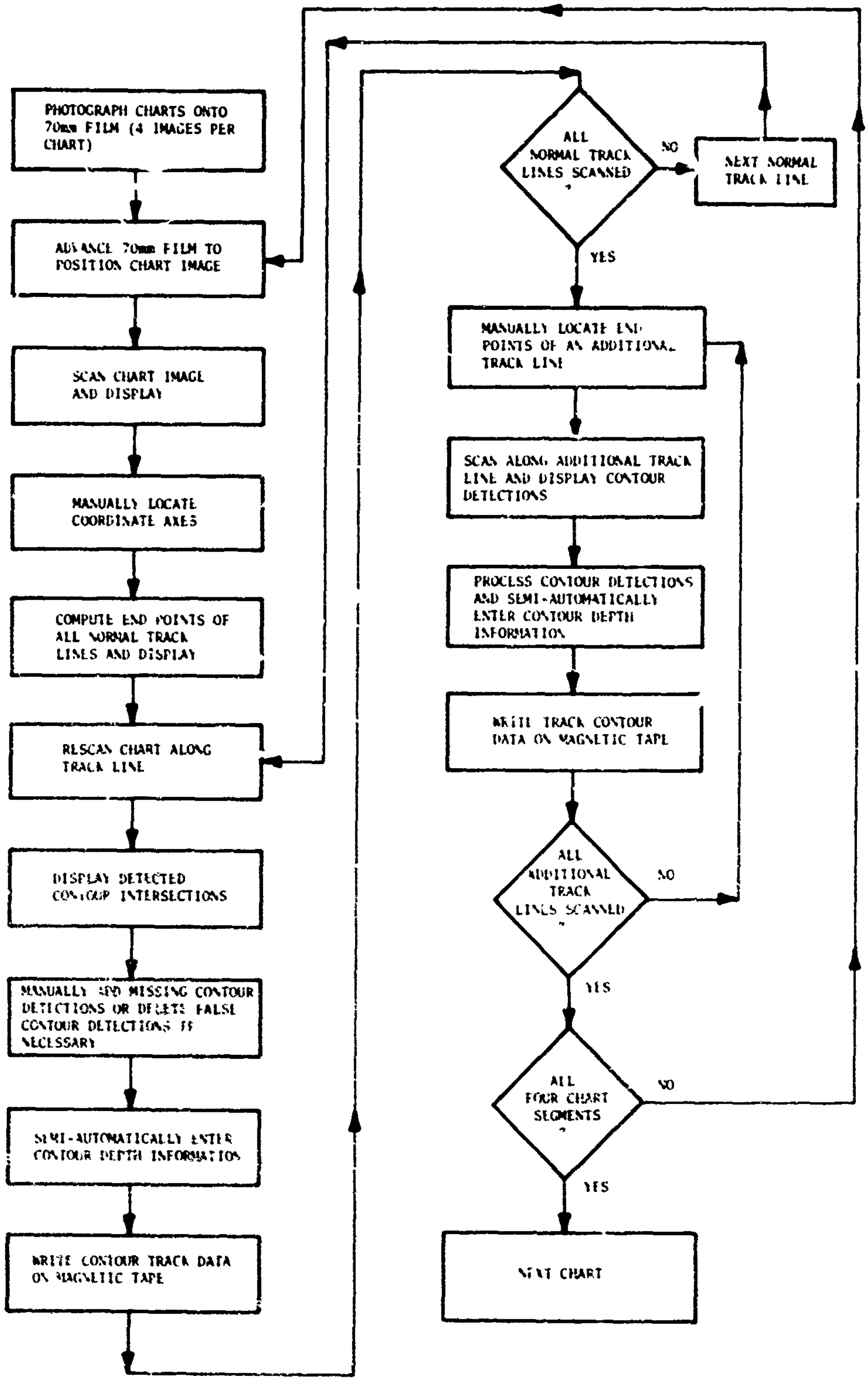

Figure 2 FLOW DIAGRAM OF THE PROCESS FOR DIGITIZING BATHYMETRY CHARTS.

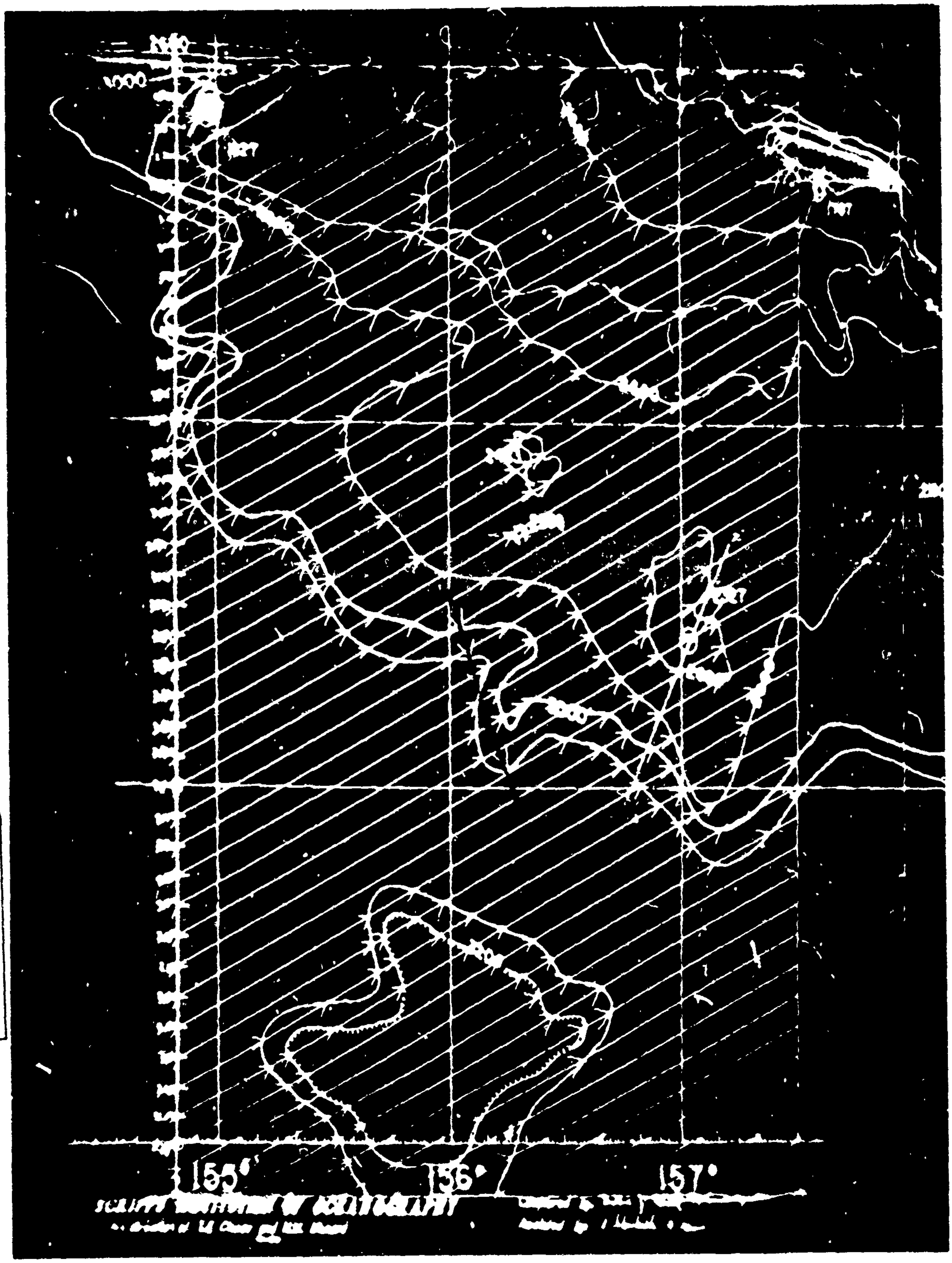

Figure 3 STORAGE OSCILLOSCOPE DISPLAY OF A PROCESSED BATHYMETRY CHART. THE ARROW POINTERS ON THE TRACK LINES SHOW THE LOCATIONS OF THE AUTOMATIC CONTOUR DETECTIONS. ONE ADDITIONAL TRACK LINE HAS BEEN SCANNED IN THE CENTER OF THE IMAGE.

automatic depth assignment features that speed up the manual entry of the depth information. In normal operation the system sequentially moves the cursor through the list of contour detections. Additionally, the operator may manually move the cursor as desired using the track ball. The location of the cursor indicates to the system operator the "current" position that the system is considering. Table 1 indicates the various operations that are available to the operator for manually processing the chart. The operator may manually enter the depth for a current contour detection or he may indicate to the system that the depth of the current detection is either the same as the depth of the previous adjacent detection on the track line or different by the standard increment (normally 200). The operator may also delete a specific contour detection on the track line or by using the track ball to position the cursor, he may add missing contour detections. The end of the track line on the outside edge of the chart is always considered a contour detection and a depth value is assigned it even if a contour does not go through this point.

In addition to the manual entry of depth information, the system provides two automatic features to speed up the depth entry process by minimizing the amount of operator interaction required. The first of these processes is a interpolation of depth values. If the depth values are assigned to two non-adjacent contour detections on a track line, the interpolation process will automatically assign depth values to the contour detections in between if and only if there are the proper number of contour detections for the interpolated depth assignments to be added in multiples of the standard increment.

The second automatic feature used to speed up the assignment of depths to the contour detections is a line following process. This process is used to follow the detected contour back to the intersection of this same contour with the previous track line for which depth has already been assigned. If the line following process is successful for a contour detection the depth assigned for that contour intersection with the previous track line is automatically assigned to the detection of the contour with current track line. The combination of the interpolation process on the line following process reduces the time required for the entry of depth information on a typical bathymetry chart.

After the depth values are assigned to the contour detections for the track lines, the system searches through the list of detected contours and indicates to the operator any inconsistencies in the depth assignments. An inconsistency occurs when two adjacent contour detections have depth assignments that are different by more than the standard increment. The operator then has the option of reassigning the depth values to the contours or retaining the inconsistency as may occur in the case of steep slope areas.

After all of the contour detections on track line are processed and depth values are assigned, the contour depth data is written on magnetic tape, the next track line is scanned, and the contour depth detections are displayed to the operator. This process is repeated until all normal track lines have been processed for the section. The operator may then indicate the end points of auxiliary track lines using a track ball to move a cursor and these additional track lines are scanned and processed in a similar way. When all normal and auxiliary track lines have been processed for the section of the chart, the image of the next section of the chart is positioned in the flying spot scanner and the process is repeated.

Section 5

DETAILS OF THE SYSTEM PROCESSES

5.1 CHART INITIALIZATION

After each section of the chart is scanned and displayed for the operator, the operator manually locates the coordinate axes on the chart image using the track ball and cursor. This process involves locating the coordinate axes at 1° intervals in latitude. This is necessary because of the inherent non-linearity in latitude on the Mecator projections. The system assumes that within each 1° segment in latitude, the chart is linear. In processing a section of the chart, the operator may select either a 2, 2-1/2 or 3° section in latitude to process depending on the specific contour characteristics.

When the entry of the coordinate axes on the chart is completed, the system computes the end points on all regular track lines. The track lines are numbered consecutively and processed in the order shown in Figure 4. If the normal track lines are not horizontal on the chart, then the first track lines in Section 1 and 2 are always horizontal, that is oriented in the east west direction parallel to the coordinate axes. The remaining track lines are at the angle designated by the operator. The track lines always begin on a five minute interval mark on the latitude axes for track lines oriented at angles less than approximately 45° and on the five minute marks on the longitude axes for track lines that are at angles greater than approximately 45°. The end points of the track lines are always defined by the locations of the five minute interval marks on one set of axes. Thus, the track lines will not be precisely parallel on charts in which the non-linearity in latitude is significant as in the polar regions. The track lines are defined as straight lines on the Mecator projection charts, not as straight lines on the earth's surface. Scanning along a track line always proceeds from bottom to top relative to the scanner coordinates, not the chart coordinates, and thus the order of the data on the track line depends on the specific orientation of the charts and the track lines. In other words, although the data points may be ordered

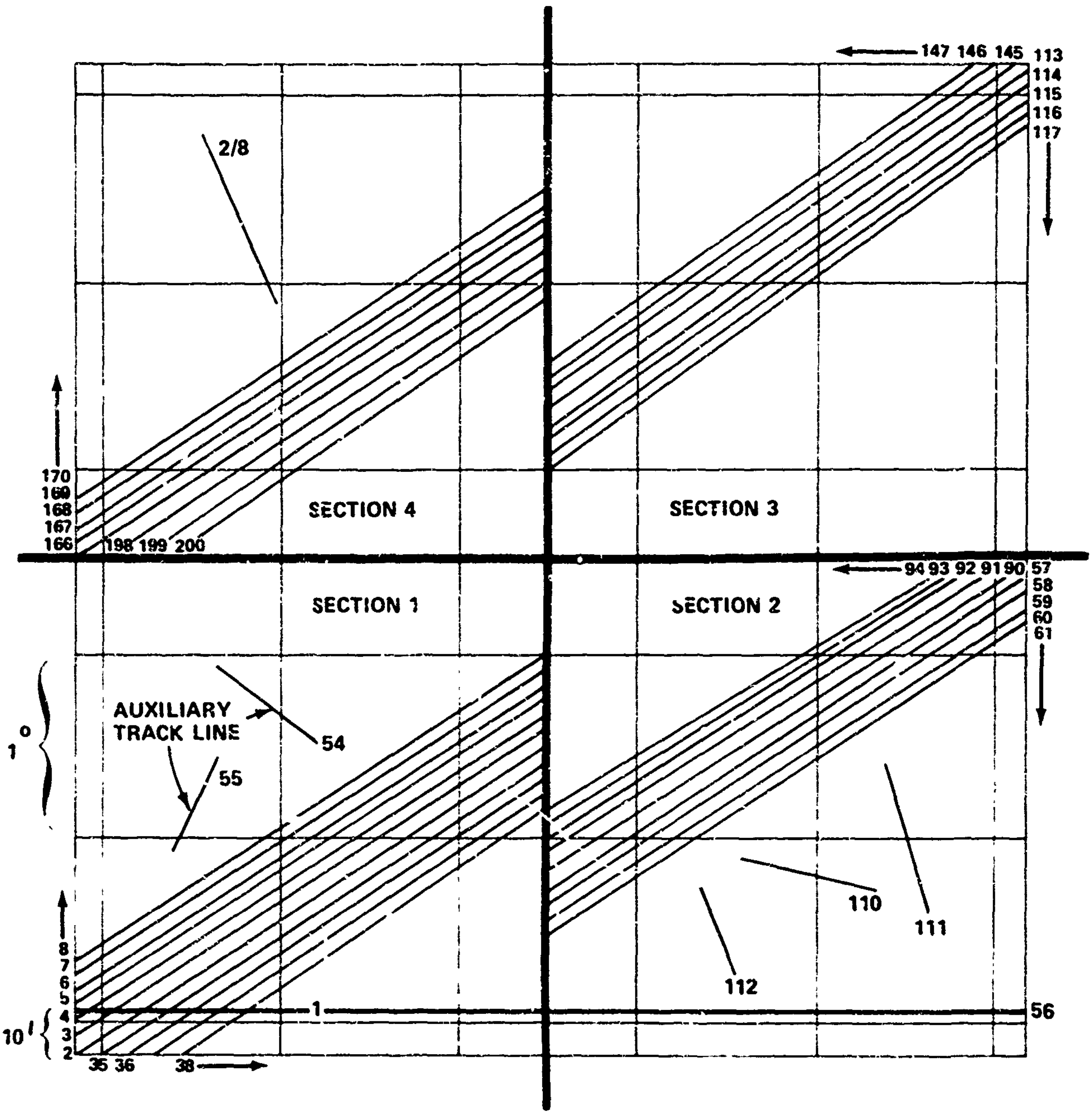

Figure 4 ORDER OF THE TRACK LINE SCANS. FOR HORIZONTAL NORMAL TRACK LINES, THE TRACK LINES ARE ORDERED FROM BOTTOM TO TOP IN SECTIONS 1 AND 2 AND FROM TOP TO BOTTOM IN SECTIONS 3 AND 4

from bottom to top or from top to bottom along any particular track line. The contour detections are always ordered by their position on the track line, and not by the order in which they were detected or processed.

5.2 CONTOUR LINE DETECTION

The method for detecting the intersections of contours with a track lines uses a moving-window procedure. In the moving-window concept, a small region or small area of the chart image is processed to determine if a contour passes through the center of the region. The region or window is then moved slightly along the track line and the process repeated. In this way the detection of the contours is based on computations over a small area of the chart rather than on the single point along the track line (Figure 5). The window is a square region of the chart approximately 4 minutes in size on a typical bathymetry chart. The window is moved in steps of approximately 10 seconds in size along the track line.

In determining if a contour goes through the center of the window, the gray level of the center point of the window is sampled to determine if its value is above the minimum gray level threshold which represents the background level of the paper. If the gray level is indeed above this value, then the adjacent samples of the chart along the track line are used to determine if the center point of the window is at a local peak of the gray level density. A local peak of gray level would occur in the center of a contour. If a local peak is detected, then the chart image within the window is sampled along 8 slits or direction. Each slit represents samples of the chart image along a straight line with the center of the line of samples being at the center of the window (See Figure 6). If a well-defined contour passes through the center of the window one of the slits will lie along the contour and thus the sum of the gray level values along the slit will be much greater (darker) than the slit sums of the other 7 slits. The direction of this slit with the highest slit sum is considered to be in the direction of the contour. If a feature other than a contour, such as a character or other "blob" type of feature goes through the center of the window, then there will not be a slit

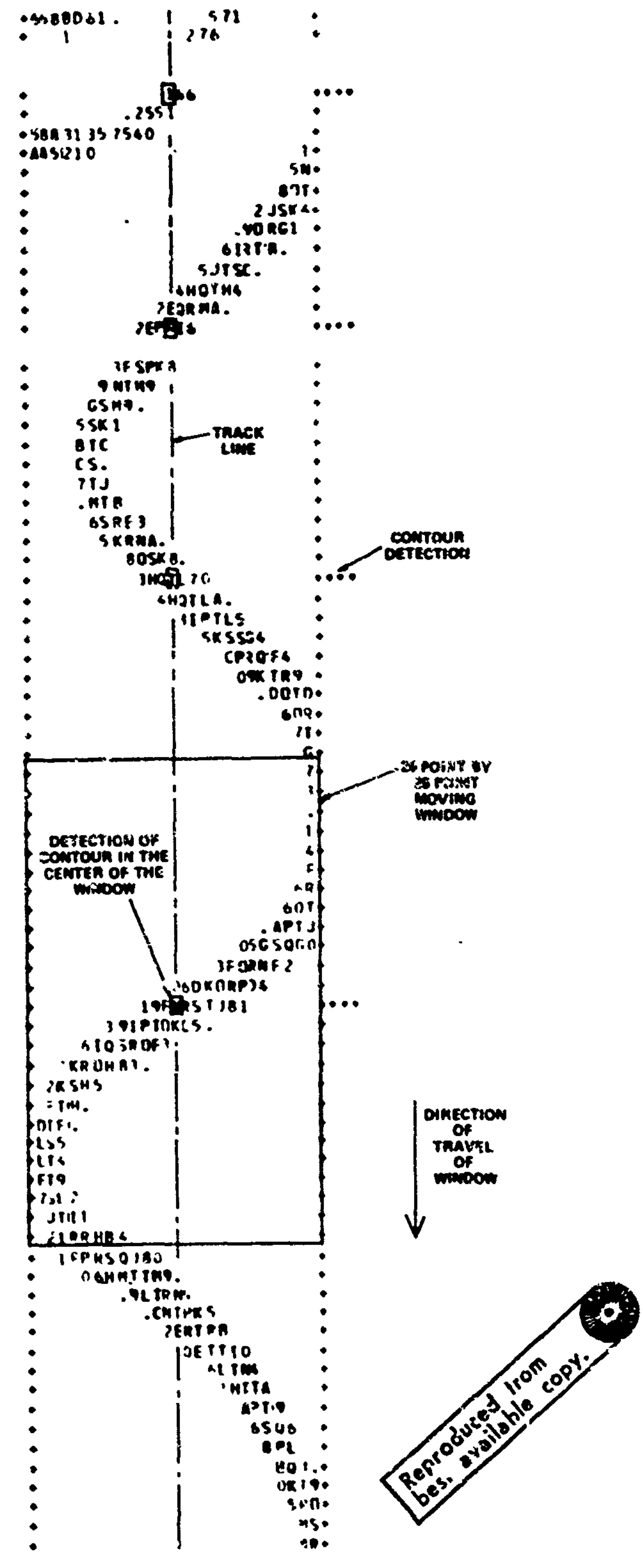

Figure 5 MOVING WINDOW CONTOUR DETECTION PROCESS

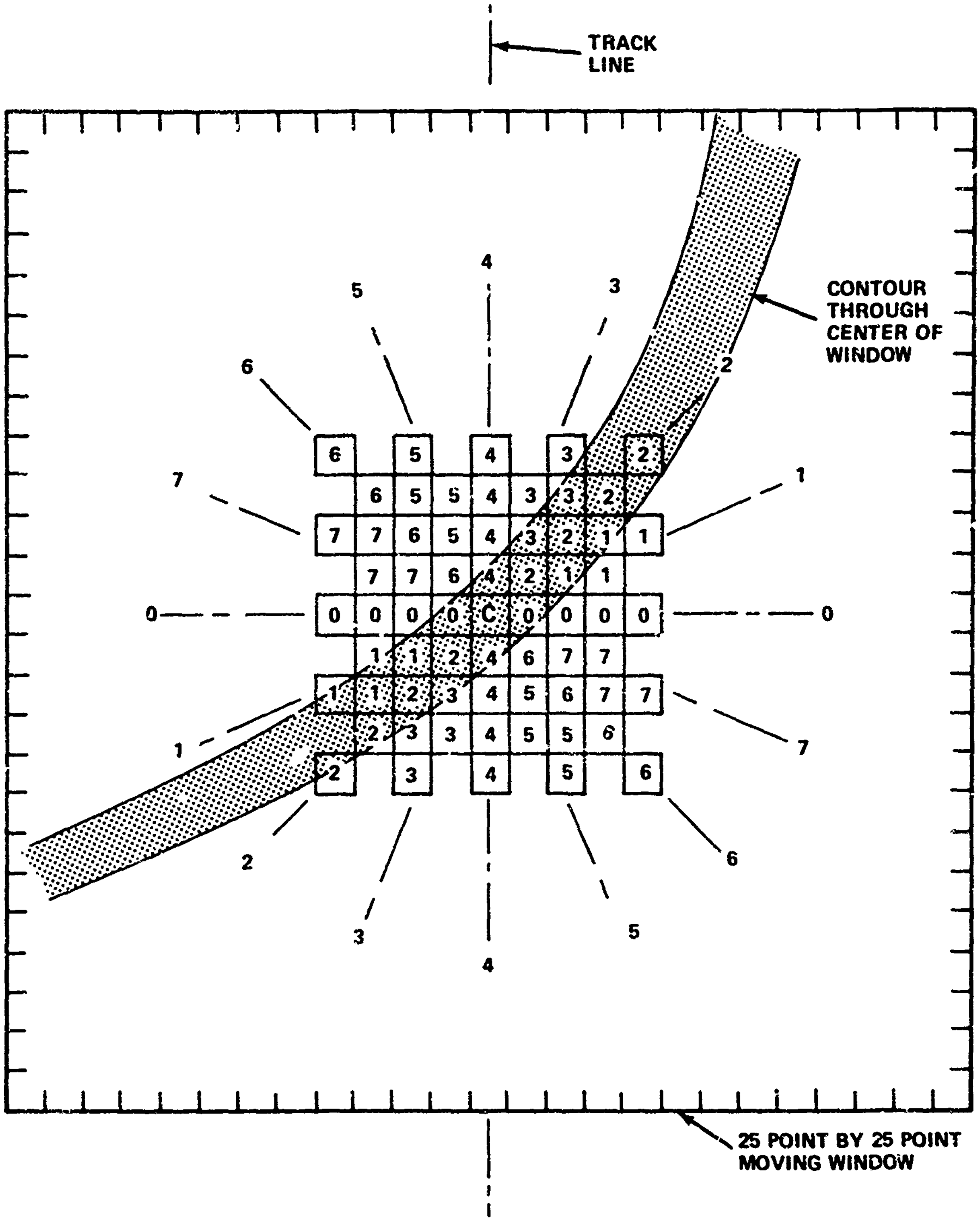

Figure 6 THE EIGHT SLIT DIRECTIONS USED IN THE DETERMINATION OF THE DIRECTION AND QUALITY OF THE DETECTED CONTOUR AT THE CENTER OF THE WINDOW. THERE ARE EIGHT SAMPLE POINTS FOR EACH SLIT DIRECTION

which exhibits a gray level sum much greater than any of the other slits. The comparison of the slit sum for the slit with the largest gray level value to the average of the slit sums from the other slits is thus used to discriminate between well defined contours and "blob" type features.

The slit sum test can discriminate between well-defined contours and non-line type of features. However, it cannot discriminate between well-defined contours and tic marks or characters which "look like" contours. Thus, the next test is the determination of the continuity of a contour detection within the window. Contours are generally continuous through the window whereas tic marks and characters are not continuous. The process for determining the continuity of the contour detection is a line following process. Under this process the system "moves" from one point on the contour detection to an adjacent point using sample points on the contour. The particular sample point with the highest gray level value is taken as the point in the center of the contour and the system moves to this point next. The selection of the sample points is based on the direction of the previous step taken. This process is repeated until the contour is followed to the edge of the window. The process is then repeated along the contour in the other direction. An important feature of this line-following process is the storage of information indicating the previous steps that the line follower had taken. This information is used to prevent the line follower from back tracking or taking a step to a location on the contour where it had previously been. A contour detection is considered to be continuous and hence a valid contour if it is followed to the edge of window in both directions.

5.3 LINE FOLLOWING FOR AUTOMATIC DEPTH ASSIGNMENT

The automatic assignment of depth values utilizes a second line following process. This process is utilized to follow a contour detection on a current track line back to the intersection of this contour with a previous track line. The depth value assigned to this contour on its intersection with the previous track line is automatically assigned to the detection on the current track line if this second line following processing is successful.

The line following process utilized in this stage is significantly different from the continuity line follower described above. The continuity line follower is efficient for following contours over very short distances but because of the many samples of the contour required, it would take too much time to be practical for following contours over longer distances. In order to follow contours over longer distances it is more efficient to periodically sample the contour at widely spaced intervals based on the estimated location of the contour.

In this line following algorithm, a scan of the chart image is made in a circular pattern starting at the current detection of the contour and ending at the intersection of the circular pattern with the contour at a different point. A new circular scan begins at the center of the first circle scan and ends when the contour is again intersected further down the contour. The process terminates when the line following crosses the location of the previous track line. By repeating this process, the contour may be followed over long distances in a minimum amount of time. This process is shown in Figure 7. Since the bathymetry charts are not clean in a sense that the contours may intersect coordinate lines or characters, the line following process used for the automatic depth assignment follows the contour on both "edges" of the contour. If the line following process along each edge terminates at approximately the same point, then the line following is considered to be successful. If a contour intersects a coordinate line, the line following process on one side of the contour will not terminate at approximately the same location as the line following process on the other side of the contour since they will tend to follow the intersected coordinate line in different directions. Thus the system concludes that the line following was unsuccessful and no automatic depth assignment is attempted. Additionally, if a contour is followed for more than a fixed distance, the line following is terminated and classified as unsuccessful. The line follower is capable of following a contour around depth characters and tic marks which may appear on the contour.

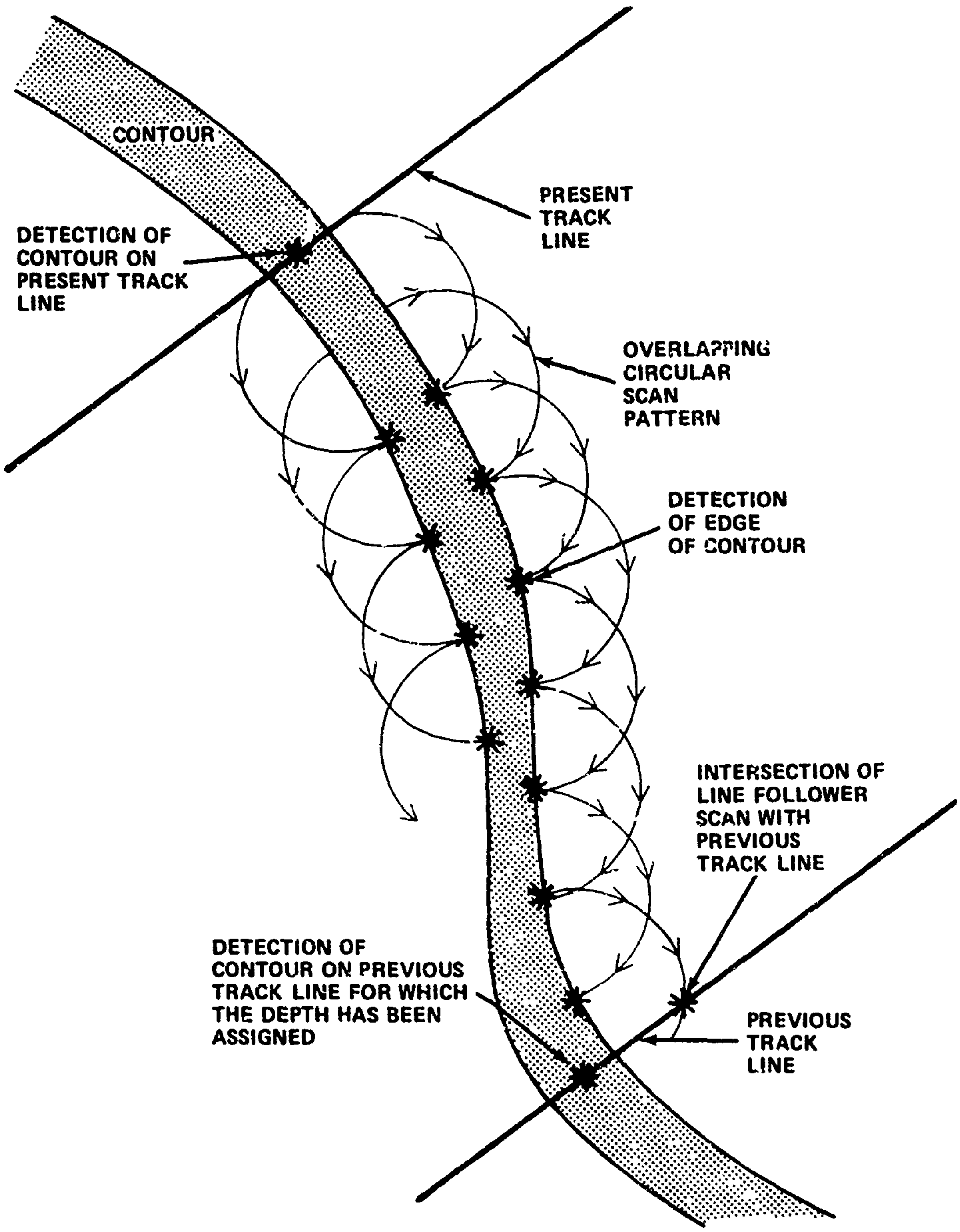

Figure 7 THE LINE FOLLOWING PROCESS - THE LINE FOLLOWER USES AN OVERLAPPING CIRCULAR SCAN PATTERN TO FOLLOW A CONTOUR FROM THE DETECTION ON THE PRESENT TRACK LINE TO THE INTERSECTION OF THE CONTOUR WITH THE PREVIOUS TRACK LINE - BOTH EDGES OF THE CONTOUR ARE FOLLOWED

The results of the line following process for a track line is a list of tentative locations of the contour intersections with the previous track line. These contour intersections are then compared to the list of detections from the previous track lines. If two detections match up within a fixed distance (approximately one minute of great circle angle), then the depth for this previous contour detection is assigned to the matching present contour detection.

Section 6

DATA OUTPUT

The contour data is written on 9 track magnetic tape in an IBM compatible tape format. Figure 8 is a printout of the data from a typical chart as written on magnetic tape. Data includes the chart number, the date, the section number (1-4), the track line number and the longitude, latitude and depth for each detection on the track line. The detections for each track line are ordered in the output record in the order of their location on the track line, not in order as they were detected or processed. However, they may be ordered in the record either from right to left or from left to right on the chart depending on the section of the chart and the slope of the line.

The 9 track IBM compatible tape is converted to a 7 track CDC compatible tape on Calspan's IBM 370/165 computer. The contour depth data is written on the CDC compatible tape with each track line beginning a new physical record. All of the data from one chart is contained in a single file. The data record for each track line includes a header which contains the chart identification number (MSQLOC number), date, track number, etc.

The tape is written as a 556 BPI, 7 track, BCD tape with even parity. The records are blocked in groups of 2080 bytes. Each physical record contains 26 logical records, 80 bytes in length. The header information is contained in a separate record which precedes the x, y and depth information for a single track. The eighth word of the header record contains the number of logical records which contain information for a specific track line.

NEW CHART, MSG NUMBER = 2106   DATE = 5/ 8/73

SECTION NUMBER = 1

	LONGITUDE	LATITUDE	DEPTH
TRACK LINE	1		
1	156.178	28.844	3180
2	155.617	28.844	3180
TRACK LINE	2		
1	156.211	28.911	3180
2	155.539	28.917	3180
TRACK LINE	3		
1	156.256	28.983	3180
2	156.044	28.983	3200
3	155.639	28.983	3200
4	155.505	28.981	3180
5	154.828	28.983	3145
TRACK LINE	4		
1	156.306	29.078	3180
2	156.117	29.072	3200
3	155.556	29.078	3200
4	155.417	29.078	3180
5	154.824	29.078	3150
AUXILIARY TRACK LINE	5		
1	156.500	32.000	2200
2	156.589	32.039	2000

SECTION NUMBER = 2

	LONGITUDE	LATITUDE	DEPTH
TRACK LINE	6		
1	158.156	28.844	3180
2	157.606	28.850	3180
TRACK LINE	7		
1	158.206	28.911	3180
2	157.539	28.917	3180
TRACK LINE	8		
1	158.29[illegible]	29.078	3180
2	158.102	29.072	3200
3	157.572	29.072	3200
AUXILIARY TRACK LINE	9		
1	158.711	30.189	3000
2	158.628	30.200	3000
3	158.337	30.239	3000

Figure 8- TYPICAL CONTOUR DETECTION DATA PRODUCED BY THE PROCESS FOR DIGITIZING BATHYMETRY CHARTS

The information contained in the header and the number of characters allotted for each word is as follows:

	Information	Characters
1)	Chart identification number	4
2)	Date	6
3)	Section number (1 through 4)	1
4)	Auxiliary flag (0 for normal track, 1 for auxiliary track)	1
5)	Partial digitization flag (0 for complete chart, 1 for partial chart)	1
6)	Track line number	3
7)	Number of detections in track line	3
8)	Number of 80 byte records written on tape for this track line	3
9)	0	1
10)	0	1

When the chart identification number becomes zero, this indicates the end of data for the chart. However, the physical record for the track may extend past this number and should be ignored.

Each of the logical records contains the x, y, and depth information from four detections followed by 8 blanks. The format of each of these items is as follows:

Information	Format
x	S999.999
y	S999.999
depth	9999

Section 7

SYSTEM PERFORMANCE

Ten charts were used in the evaluation of the performance of the bathymetry chart digitizing system. This performance evaluation indicated that while the time required to digitize a bathymetry chart is highly variable and dependent on the individual characteristics of the chart, this system achieves a speedup of chart digitizing by a factor of approximately 3 relative to the completely manual methods considered by ONR. The most critical factor in the chart quality appears to be the extent to which adjacent contour lines become very closely spaced. On charts with many close contours and closed contours in the form of concentric rings, most of the digitizing time is spent by the operator in trying to determine and assign the proper depth values.

The specific results of the system performance evaluation are as follows. Chart MSQLOC number 1294 required approximately 1 hour and 15 minutes to complete the digitizing of the entire chart. This chart is simple with only a few contours. Chart MSQLOC No. 1293 required approximately 1 hour and 45 minutes. This chart, while containing more contours than Chart No. 1294, has many well separated well defined contours for which the automatic depth assignment processes (the interpolation and the line following processes) worked very well. On the other hand, the Chart MSQLOC No. 0931 required approximately 5-1/2 hours to digitize. This chart contains many closed contours in the form of concentric rings with the contours being very close together. On a chart with these characteristics the automatic line follower is not capable of following individual lines that are very close and thus does not significantly aid the operator in contour depth assignment. Most of the time was required by the operator in order to resolve the individual contour detections in these areas of very close contours, to determine the proper depth, and to manually assign depth for the individual contours. On this chart, an attempt was made to provide the location and depth of all contours intersecting the track lines. On future charts with these characteristics, only the major contours which define the general contour characteristics in these areas of very close contours will be used. In other words, in regions of close contours that are equally spaced,

only the "outside" contours will be used since the interpolation process used by ONR will properly replace the missing contours. Thus it is expected that the time for complex charts such as 0931 will be somewhat reduced. The time required by the system alone without any operator interaction is approximately 40 minutes per chart. This time is required for the scanning and display of the chart, the rescanning along the track lines and the display of the track detections for the operator. Thus on complex charts the vast majority of the time is required by the operator and not by the system.

TABLE I

KEYBOARD OPERATIONS

CONTROL CHARACTER	FUNCTION	
P	PLUS -	set current contour detection depth to depth of previous contour plus the standard increment
M	MINUS -	set current contour detection depth to depth of previous contour minus the standard increment
S	SAME -	set current contour depth to the same value as the depth of the previous contour
D	DEFINE -	define the depth of the current contour
A	ADD -	add a contour detection at the current cursor position
E	ERASE -	erase the contour detection at the current cursor position
C	CLEAR -	clear all depth information of the current track line
Z	PRINTOUT -	printout depth assignment on the teletype of of all contours for the current track line
O	OMIT -	omit the entire current track line
F	FORGET -	omit all remaining regular track lines for the current section
N	NEXT -	move cursor (i.e., current contour detection) to the next contour on this track line - displays assigned depth
B	BACK -	move cursor to the previous contour detection on this track line - displays assigned depth
R	REQUEST -	request for the display of the depth assignment for the contour at the current cursor position
X	EXIT -	attempt to exit from current track line

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IN REPLY REFER TO:

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31 Jan 06

MEMORANDUM FOR DISTRIBUTION LIST

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

   Classification changed to UNCLASSIFIED by authority of the Chief of Naval Operations (N772) letter N772A/6U875630, 20 January 2006.

   DISTRIBUTION STATEMENT A: Approved for Public Release; Distribution is unlimited.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

BRIAN LINK
By direction

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

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Declassified LRAPP Documents

Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Brancart, C. P.	TRANSMISSION REPORT, VIBROSEIS CW ACOUSTIC SOURCE, CHURCH ANCHOR EXERCISE, AUGUST AND SEPTEMBER 1973	B-K Dynamics, Inc.	730101	AD0528904	U
Unavailable	Daubin, S. C., et al.	LONG RANGE ACOUSTIC PROPAGATION PROJECT. BLAKE TEST SYNOPSIS REPORT	University of Miami, Rosenstiel School of Marine and Atmospheric Science	730101	AD0768995	U
NUSC TR NO. 4457	King, P. C., et al.	MOORED ACOUSTIC BUOY SYSTEM (MABS): SPECIFICATIONS AND DEPLOYMENTS	Naval Underwater Systems Center	730105	AD0756181; ND	U
MC-012	Unavailable	CHURCH GABBRO SYNOPSIS REPORT (U)	Maury Center for Ocean Science	730210	ND	U
Unavailable	Hecht, R. J., et al.	STATISTICAL ANALYSIS OF OCEAN NOISE	Underwater Systems, Inc.	730220	AD0526024	U
Raff rept 73-2	Bowen, J. I., et al.	EASTLANT SHIPPING DENSITIES	Raff Associates, Inc.	730227	ND	U
Unavailable	Sander, E. L.	SHIPPING SURVEILLANCE DATA FOR CHURCH GABBRO	Raff Associates, Inc.	730315	AD0765360	U
Unavailable	Wagstaff, R. A.	RANDI: RESEARCH AMBIENT NOISE DIRECTIONALITY MODEL	Naval Undersea Center	730401	AD0760692	U
Unavailable	Van Wyckhouse, R. J.	SYNTHETIC BATHYMETRIC PROFILING SYSTEM (SYNBAPS)	Naval Oceanographic Office	730501	AD0762070	U
MCPLAN012	Unavailable	SQUARE DEAL EXERCISE PLAN (U)	Maury Center for Ocean Science	730501	NS; ND	U
Unavailable	Marshall, S. W.	AMBIENT NOISE AND SIGNAL-TO-NOISE PROFILES IN IOMEDEX	Naval Research Laboratory	730601	AD0527037	U
Unavailable	Daubin, S. C.	CHURCH GABBRO TECHNICAL NOTE: SYSTEMS DESCRIPTION AND PERFORMANCE	University of Miami, Rosenstiel School of Marine and Atmospheric Science	730601	AD0763460	U
MC-011	Unavailable	CHURCH ANCHOR EXERCISE PLAN (U)	Maury Center for Ocean Science	730601	ND	U
Unavailable	Solosko, R. B.	SEMI-AUTOMATIC SYSTEM FOR DIGITIZING BATHYMETRY CHARTS	Calspan Corp.	730613	AD0761647	U
64	Jones, C. H.	LRAPP VERTICAL ARRAY- PHASE II	Westinghouse Research Laboratories	730613	AD0786239; ND	U
Unavailable	Koenigs, P. D., et al.	ANALYSIS OF PROPAGATION LOSS AND SIGNAL-TO-NOISE RATIOS FROM IOMEDEX	Naval Underwater Systems Center	730615	AD0526552	U
NUSC TR 4417	Perrone, A. J.	INFRASONIC AND LOW-FREQUENCY AMBIENT-NOISE MEASUREMENTS OFF NEWFOUNDLAND	Naval Underwater Systems Center	730619	~~ND~~ AD913668	U
USRD Cal. Report No. 3576	Unavailable	CALIBRATION OF FLIP-CHURCH ANCHOR TRANSDUCERS SERIALS 15 AND 19	Naval Research Laboratory	730716	ND	U